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Ex-Service F/A-18 Centre Barrel Fatigue Flaw Identification Test Plan

B. Dixon and L. Molent

DSTO-TR-1426

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Air Vehicles Division
Platforms Sciences Laboratory

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ABSTRACT

This report provides a generic plan for fatigue cycling and teardown of ex-service F/A-18 centre barrels for the purpose of fatigue flaw identification. It describes the accelerated fatigue test cycling program which will be applied to each centre barrel to increase the size of existing microflaws or defects so that they can be more reliably detected. It also covers the teardown, inspection and storage requirements of the project.

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Executive Summary

Fatigue testing of the F/A-18 aircraft by the Canadian Forces (CF) and Royal Australian Air Force (RAAF) in the International Follow-Up Structural Test Project (IFOSTP) found that the centre barrel had insufficient life to meet the required RAAF planned withdrawal date of between 2012 and 2015. In response to this shortfall, the RAAF has planned a series of repairs and modifications referred to as SRP1++. To reduce possible risks involved in the SRP1++ program, a teardown inspection of several ex-service centre barrels is required.

This document provides a plan for the teardown of F/A-18 centre barrels sent to DSTO for examination. The teardown process involves a number of steps, which have been outlined herein. After initial inspection of a centre barrel, it will be fatigue cycled to increase the size of potential fatigue cracks or flaws (corrosion, mechanical damage etc.) in the structure and thus enable more of the cracks to be reliably detected.

Once accelerated fatigue cycling is complete, the centre barrel will be disassembled to part level and inspected for fatigue cracks, corrosion and mechanical damage according to the procedures in this document. Any defects found will be stored in a database and further analysis of the defect will be undertaken using quantitative fractography.

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Contents

1. BACKGROUND 1

2. INTRODUCTION 1

3. AIM AND OBJECTIVES 3

4. FATIGUE ENHANCEMENT METHODOLOGY 4
   - 4.1 Pre-Test NDI Inspection 5
   - 4.2 Test Rig Design 5
   - 4.3 Loading 10
   - 4.4 Test Instrumentation 10
   - 4.5 Fatigue Enhancement End Criteria 10

5. TEARDOWN PROCESS 11
   - 5.1 Test Article Disassembly 11
   - 5.2 NDI Inspection 11
   - 5.3 Entry Into Database 12
   - 5.4 Notice Of Structural Deficiency 12
   - 5.5 Quantitative Fractography 12
   - 5.6 Centre Barrel Disposal/Storage Instructions 13
   - 5.7 Teardown Report Requirements 13

6. CONCLUSION 13

7. ACKNOWLEDGEMENTS 14

8. REFERENCES 15

APPENDIX A: INSPECTION CARDS 16

APPENDIX B: IDENTIFICATION AND DATABASE REQUIREMENTS 17

APPENDIX C: QUANTITATIVE FRACTOGRAPHY 20

APPENDIX D: DEFECT DEFINITIONS 23

List of Tables

Table A1 - FT55 Teardown Inspection Cards to be used in Centre Barrel Inspection.... 16
Table D1 - Standard Damage Type – Fatigue Defects Codification Table 24
Table D2 - Standard Damage Type – Mechanical Defects Codification Table................ 25
TableD3 – Standard Damage Type – Corrosion Defects Codification Table 25

List of Figures

Figure 1 - Diagram of the F/A-18 Centre Barrel 2
Figure 2 – Photograph of the F/A-18 Centre Barrel 3
Figure 3 - Centre Barrel Test Rig Design Schematic 6
Figure 4 – FS488 Free-Standing Bulkhead Test Rig 7
Figure 5 - Centre Barrel Test Rig Detailed Design 8
Figure 6 - Detailed Design of Beam to Wing Lugs Joint 9
Figure 7 – Normalised mini-FALSTAFF Sequence Exceedances...................................... 11
Figure C1 - QF Decision Flow Chart 22

List of Abbreviations and Acronyms

CBR	Centre Barrel Replacement
CF	Canadian Forces
DC	Durability Critical
DIL	Damage Item Location
DSTO	Defence Science and Technology Organisation
FALSTAFF	Fighter Aircraft Loading Standard For Fatigue Evaluation
FC	Fracture Critical
HFEC	High Frequency Eddy Current
IFOSTP	International Follow-On Structural Test Project
LPI	Liquid Penetrant Inspection
MDA	McDonnell Douglas Aircraft Corporation (now Boeing)
NDI	Non Destructive Inspection
NSD	Notice of Structural Deficiency
PSL	Platforms Sciences Laboratory
QF	Quantitative Fractography
RAAF	Royal Australian Air Force
USN	United States Navy
WRBM	Wing Root Bending Moment

1. Background

After the introduction of the F/A-18 aircraft into service with Royal Australian Air Force (RAAF), the usage of the aircraft was found to be statistically different than the design spectrum used by the then manufacturer, McDonnell Douglas Aircraft Corporation (MDA). The differences were sufficient to require further verification through fatigue testing. A similar problem faced by the Canadian Forces (CF) resulted in a joint project. It was decided that applying usage representative RAAF/CF loading in the International Follow-On Structural Test Project (IFOSTP) series of tests would produce data sufficient to establish the structural integrity of both Canadian and Australian aircraft. The project consisted of centre fuselage and wing tests (the responsibility of the CF) and an aft fuselage and empennage test which was the responsibility of the RAAF [1].

The F/A-18 centre barrel is shown in Figures 1 and 2. Its main structural elements are the FS453, FS470.5 and FS488 bulkheads, which carry wing loads into the fuselage. It was found from the IFOSTP centre fuselage test, FT55, that the centre barrel Safe-Life was insufficient (without modification) to meet the required RAAF planned withdrawal date of between 2012 and 2015. A centre barrel replacement (CBR) program was investigated to address some of the deficiencies identified through FT55. The CF and United States Navy (USN) have already commenced a CBR program. For RAAF implementation, two main problems with the CBR program were highlighted[1]; The program would be difficult to run in-country since the expertise to carry out the program was thought to be insufficient, and the availability of aircraft during the program would be insufficient to meet the operational needs of the RAAF. For these reasons combined with the predicted expense of such a program, the RAAF are examining alternative strategies to a CBR (referred to as SRP1++) [2].

2. Introduction

In order to mitigate the risks posed by possible uncertainties in the SRP1++ program (eg. onset of wide spread fatigue damage, additional failure locations, corrosion, etc.), a teardown and inspection of several ex-service centre barrels is required [2]. Further, a recent probabilistic risk and reliability study [3] of the F/A-18 centre barrel highlighted the need for more service life data from fleet aircraft to confirm the fatigue test results as well as corroborate the assumptions made during that study.

Since the CF and USN are both engaged in the early stages of a CBR program, several centre barrels will be available for tear down in the near future. This paper presents the scope and aims of such a tear down program for used centre barrels. It is based on the procedures defined for the generic teardown of IFOSTP test articles [4].

[1] TFLM/01/19 (16) Dated 13 Sep 2001.

The task will consist of initial conventional inspections, accelerated fatigue testing, then dismantling the used centre barrels to part level, followed by a detailed inspection of all areas of structural significance. In some cases, quantitative fractography (QF) will be performed on observed cracking defects to obtain crack growth data and to determine the size, nature and cause of discontinuities that initiate fatigue cracking.

The following philosophy has been developed and will be applied to all centre barrels examined following fatigue enhancement, which will involve fatigue testing prior to teardown to increase the probability of detecting the defects present.

DSTO investigations [3] suggest that the largest "likely" cracks in the bulkheads will be less than 1mm deep at the time a centre barrel is replaced. Since the detectable crack depth threshold for current NDI (using high frequency eddy current (HFEC) detection) is greater than 1 mm, these cracks may not be found.

To significantly improve the probability of detecting these sub-threshold cracks, an increase in their size by accelerated fatigue testing the centre barrels is required. This will involve applying cyclic loads to the retired centre barrels in a test rig. Loading should be of sufficient magnitude and duration to ensure that any existing cracks will be grown to a size that ensures their detection under laboratory conditions.

The program will be referred to as: Flaw Identification through the Non-representative Application of Loading (FINAL).

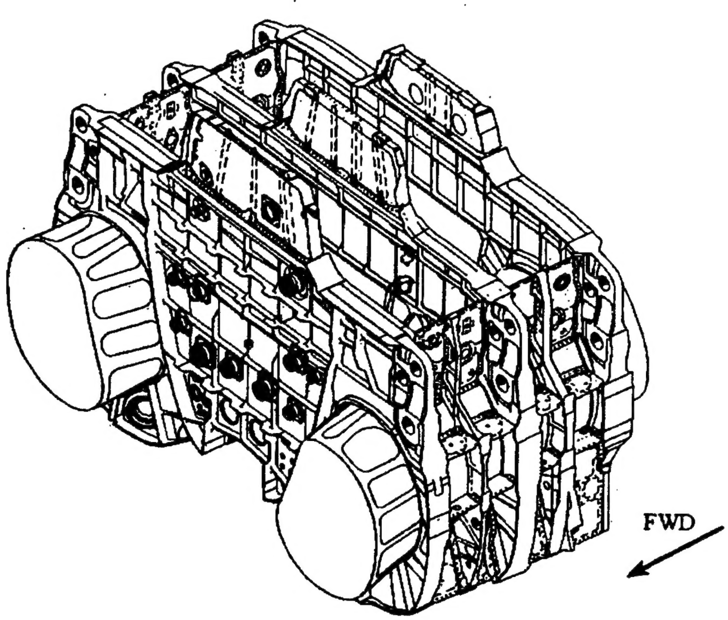

Figure 1 – Diagram of the F/A-18 Centre Barrel

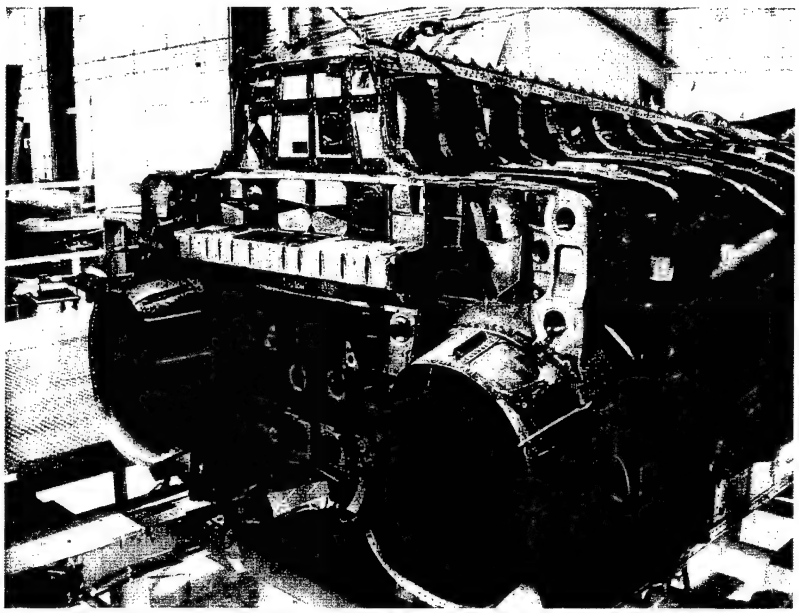

Figure 2 – Photograph of the F/A-18 Centre Barrel

3. Aim and Objectives

The aim of this paper is to describe the process of fatigue cycling and to outline a generic teardown philosophy for the F/A-18 centre barrels sent to DSTO for examination.

The objectives of the teardown of F/A-18 ex-service centre barrels are:

a. To determine whether there exists in-service aircraft centre barrel damage not detected (and thus not accounted for) through the fatigue test process. This includes corrosion and mechanical damage that are a result of the service environment. Known F/A-18 defect locations are described in [5].

b. To determine and quantify the types of defects or degradation leading to cracking in fleet aircraft.

c. To ensure that future decisions on the CBR program are based on as much relevant information about the structural integrity of the in-service centre barrel as possible; and

d. To provide data that will enhance the current risk and reliability method deliberations with regard to the F/A-18 aircraft.

The tests cannot and are not intended to represent full-scale fatigue tests, which are used to validate the procedures used to design an airframe to a specified life. However, by providing additional opportunity for identification of potential critical locations, the test and analysis program will assist in reducing the risk of structural failure in fleet aircraft.

4. Fatigue Enhancement Methodology

When tearing down ex-service structure to compare the critical locations with full-scale fatigue test article data, the expectation is that any cracking in the structure will be very small. The safe-life method of ensuring airworthiness dictates that full-scale fatigue testing is carried out for 3 or more times the expected life of the airframe as recommended by DEFSTAN [6]. Thus, if a crack reaches failure at the end of these 3 life times, it is expected that this same crack would have been very small while the aircraft remained in the fleet service life band (one third the total time that the crack was growing). Further, if the growth of the critical crack (approximately 10 mm in depth) was exponential (typical of many cracks unaffected by residual stress and/or load shedding [3]) and grew from a typical crack like flaw size (approximately 0.01 mm [3]), then the size of such a crack at one third the full-scale fatigue test life would be only about 0.1 mm deep. This size of cracking would be very difficult to find without knowing the exact position in which to look. For this reason it will be necessary to grow cracks from an ex-service aircraft to a reasonable size prior to any teardown.

The method proposed in this plan is to increase the size of potentially existing cracks in the structure such that small or otherwise undectable cracking is revealed. This is achieved by applying wing root bending moment (WRBM) fatigue cycling to the ex-service centre barrels. The requirements for such a fatigue enhancement test to provide useful data are as follows:

1. The loading should be applied in blocks that are easy to "read" during QF so that the demarcation between the service loading and the fatigue enhancement can be easily distinguished in the crack surfaces. This will allow the size of cracks present at the end of service life to be determined; and

2. The loading should be simple enough to be applied in a reasonable time frame so that the set-up and testing phase of this process is minimised. Since this is not a fatigue test, the load sequence does not have to be accurate or representative of fleet usage.

4.1 Pre-Test NDI Inspection

Prior to fatigue enhancement, each centre barrel will be inspected to assess it's in-service condition using conventional techniques. It will then be possible to report any early damage to the RAAF. The inspectors will be instructed to find all defects that are within the capabilities of the NDI techniques used. Special attention will be paid to damage not previously seen or accounted for in fatigue testing, including corrosion and mechanical damage. The scope of this inspection is limited by the access that is possible for the assembled centre barrel. Details of the inspections required and the associated FT55 teardown inspection cards [7] are provided in Appendix A.

4.2 Test Rig Design

The rig will be a simple self-reacting system. Each bulkhead will be loaded separately through its pair of wing attachment lugs. The simple schematic of the rig design is shown in Figure 3. The centre barrel will be rotated 90 degrees, so that the wing lugs of each bulkhead are attached to an upper and lower beam. The lower beams will be attached to the laboratory test floor. A WRBM will be applied to the upper lugs through the beam and pair of actuators. An equal bending moment is applied to the lower lugs by the reacting structure.

The separate loading of each bulkhead will enable further cycling of the remaining bulkheads after each bulkhead has failed. It also means that little fatigue enhancement will occur to structure other than the three bulkheads. This was deemed satisfactory because the bulkheads are fracture critical (FC) structure and have been found to limit the life of the centre fuselage in previous fatigue tests.

The rig applies loads in a similar manner to the F/A-18 FS488 Free-Standing Bulkhead Test Rig [8]. This rig, shown in Figure 4, also applied a bending moment to the wing attachment lugs via a pair of beams and actuators. The centre barrel rig replicates this loading for the FS453 and FS470.5 bulkheads. The rotation of the FS488 bulkhead rig by 90 degrees allows for the weight of the beams and actuators to be carried without the additional supporting structure that was required by the previous rig.

Figure 5 shows the detailed design of the rig. The actuator and extension tube combination shown on the left hand side will be used to load the FS453 and FS488 bulkheads, whilst the right hand side depicts the actuator and extension tube combination used to load the FS470.5 bulkhead. It was necessary to use different actuators for FS470.5 bulkhead because there were only four actuators of the type used for the FS488 and FS453 bulkheads available. The rig was designed for a maximum WRBM of 6,462 in-kip. Each beam is constructed from back to back parallel flange channels (PFC) which are 250 mm deep with 90 mm flanges. The channel webs are 8 mm thick and the flanges are 15 mm thick. The connections between the beam and the wing lugs of the bulkheads, shown in Figure 6, consist of a central plate and a pair of links. The central plate is bolted between the two channels, whilst the links connect it to

bulkhead. Two separate links were used to provide closely mating surfaces at each of the wing lugs and thus reduce the bending in the pins, because the upper and lower wing attachment lugs have significantly different thicknesses. The channel webs are reinforced around the bolts that attach to the central plate to reduce bearing stresses.

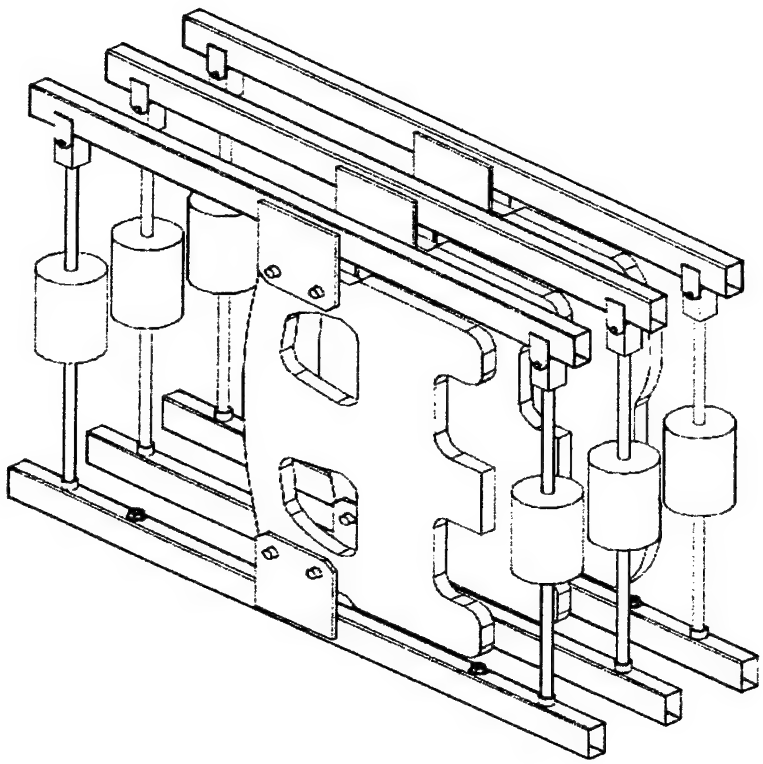

Figure 3 - F/A-18 Centre Barrel Test Rig Design Schematic

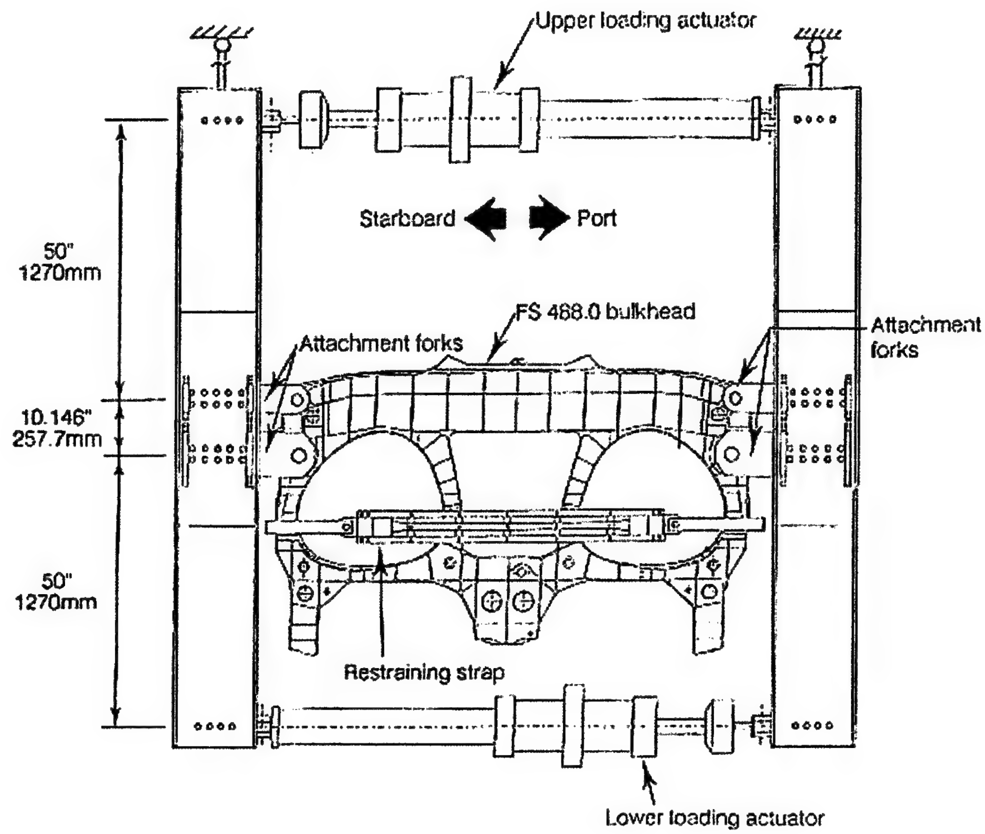

Figure 4 – FS488 Free-Standing Bulkhead Test Rig

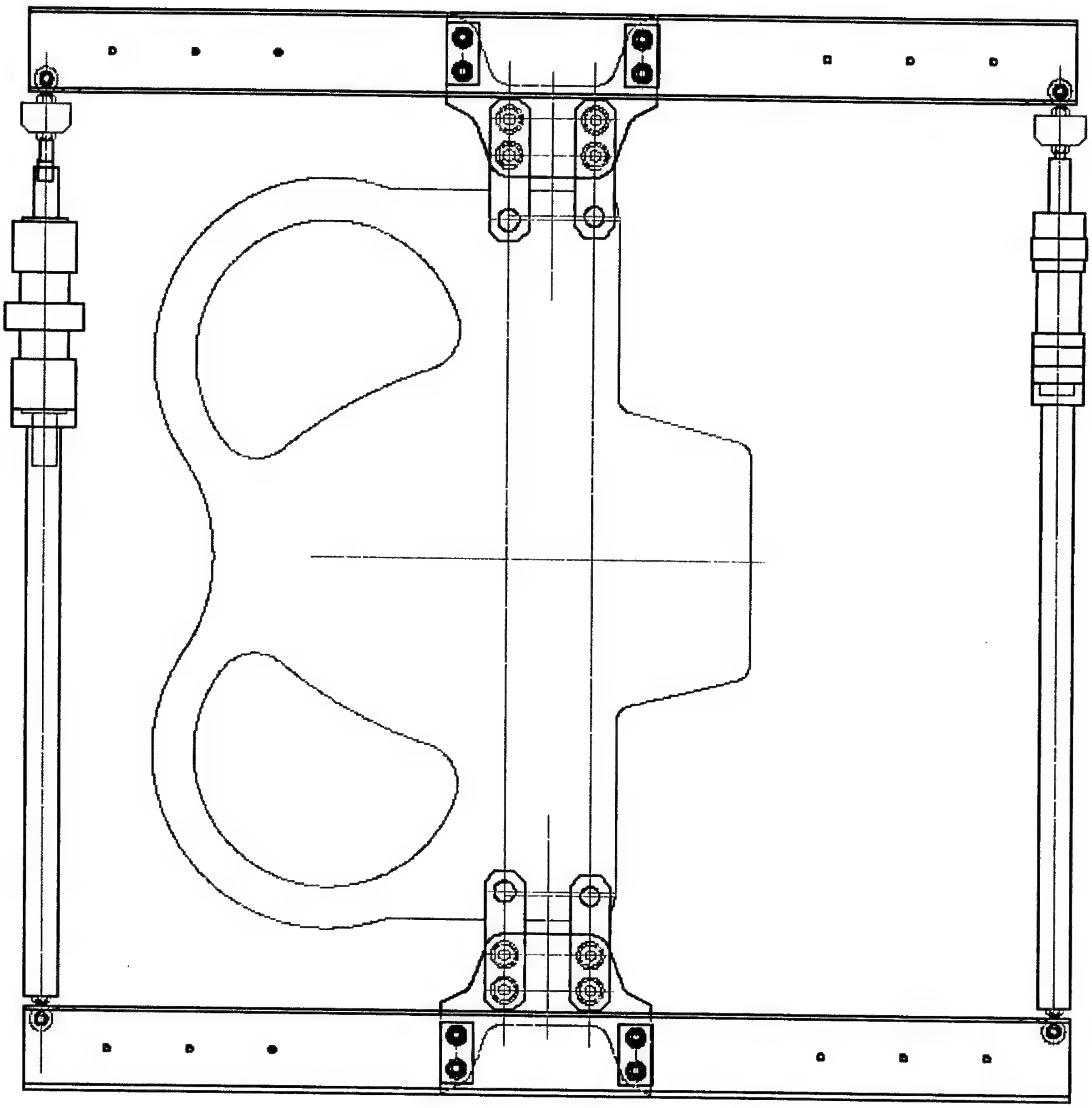

Figure 5 – F/A-18 Centre Barrel Test Rig Detailed Design

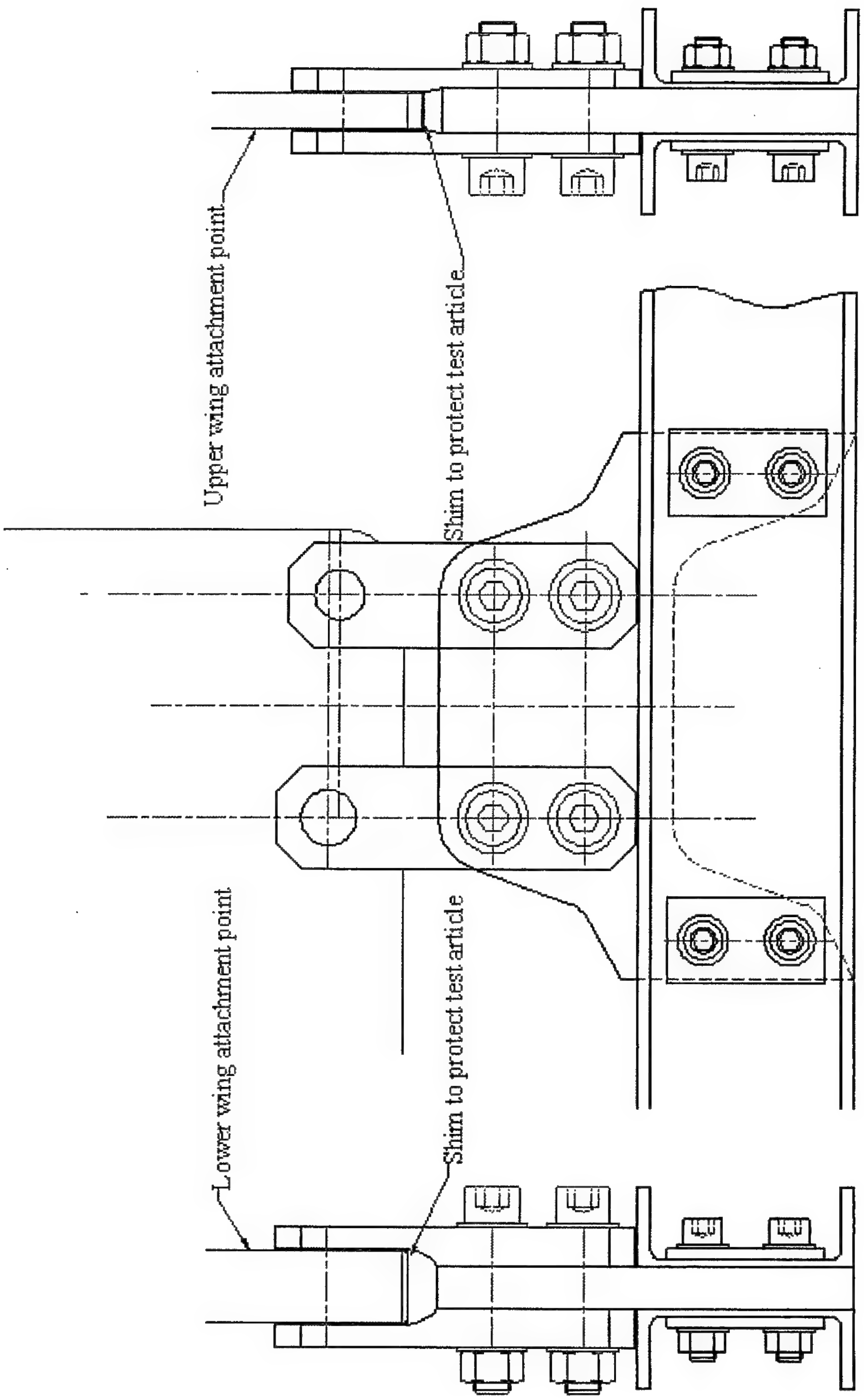

Figure 6 – F/A-18 Detailed Design of Beam to Wing Lugs Joint

4.3 Loading

The mini-FALSTAFF (Fighter Aircraft Loading STAndard For Fatigue Evaluation) sequence, equivalent to 200 flights, will be applied to the test articles. It is a truncated version of the FALSTAFF loading sequence developed by NLR (Netherlands), LBF (Germany), IABG (Germany) and F+W (Switzerland), to represent the standard load history of the wing root of a fighter aircraft [9]. The normalised mini-FALSTAFF sequence was generated using the NRL developed software "Genisis 4 Fatigue" [10]. The normalised exceedances of a single block of the sequence are illustrated in Figure 7.

The normalised sequence was multiplied 6462 in-kip to produce a WRBM sequence. The load sequence for each bulkhead was calculated by dividing the total WRBM equally between the three bulkheads. The wing root strain will be monitored at each wing attachment lug to verify the applied loading.

4.4 Test Instrumentation

Instrumentation will be kept to a minimum. In order to assess the load distribution between bulkheads the standard RAAF AFDAS (Airframe Fatigue Data Analysis System) wing root gauges will be applied to the bulkheads. A description of these gauge locations can be found in [11]. Data acquisition will allow for recording of static strain survey results. A strain survey to 80% of the maximum sequence load shall be conducted prior to cycling and a survey shall be conducted subsequent to failure and disconnection of a specific bulkhead.

4.5 Fatigue Enhancement End Criteria

The aim of the fatigue enhancement is to test each of the FS453, FS470.5 and FS488 bulkheads to failure. This should provide the maximum number of damage sites that may be detected with NDI. After the failure of a bulkhead, loading of it will cease, while the other bulkheads continue to be loaded. Testing will conclude when all three bulkheads have failed. No inspections are to be conducted and the rig will be stopped only for maintenance.

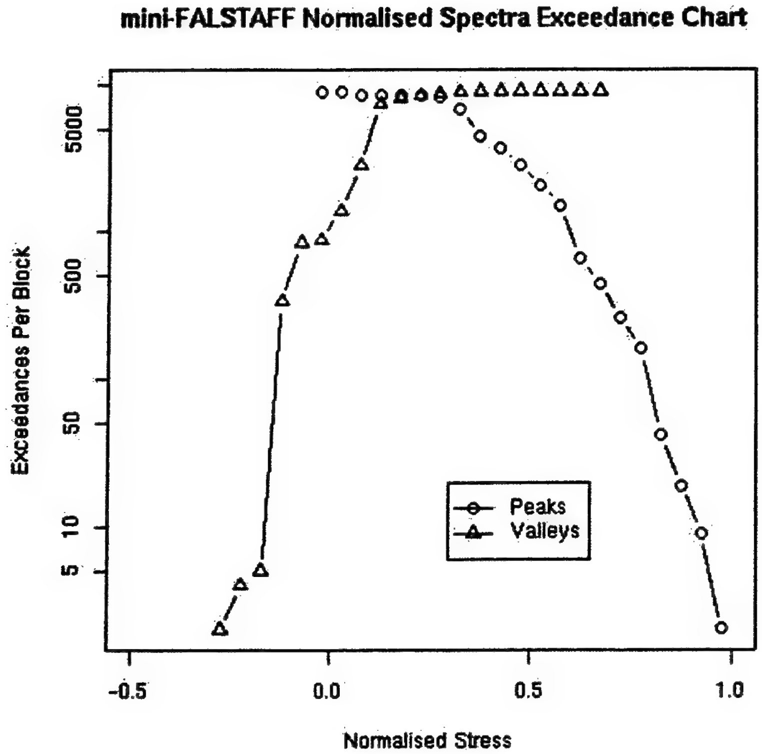

Figure 7 – Normalised mini-FALSTAFF Sequence Exceedances

5. Teardown Process

5.1 Test Article Disassembly

After the centre barrel has been removed from the test rig, a stand will be attached to the FS470.5 bulkhead and a trestle will be placed between the FS462.5 frame and the FS470.5 bulkhead. Each centre barrel will be dismantled back to front, starting with the removal of the FS488 bulkhead and moving forward to the FS453 bulkhead. Each frame and bulkhead will be removed by removing the duct and webs attaching it to the remainder of the centre barrel. The trestle will be moved forward as more of the structure is removed.

5.2 NDI Inspection

After each part has been removed from the centre barrel, it shall be inspected by a qualified NDI technician.

Using the inspection criteria described in the IFOSTP generic teardown plan [4], the following NDI requirements were determined:

a. The FS453, FS470.5 and FS488 bulkheads are FC items and have a number of areas that are non-inspectable in the fleet (though these areas are inspectable

after teardown). All surfaces and holes shall be inspected using HFEC detection and confirmed with Liquid Penetrant Inspection (LPI).

b. The FS462.5 and FS478.5 fuselage formers are durability critical (DC) items and have a number of areas that are non-inspectable in the fleet. All surfaces and holes shall be inspected using HFEC.
c. The duct skins and plates to cap the FS453, FS470.5 and FS488 bulkheads are all secondary structure. All surfaces and hole shall be inspected using HFEC.
d. All other items in the centre barrel are secondary structure and require only close visual inspection.

Inspection cards from the FT55 teardown [7] were used for items in a, b and c. They are listed in Appendix A.

5.3 Entry Into Database

When a part has been found to contain a defect using NDI, it will be identified and its details will be entered into the DSTO teardown database. A tag will also be made and attached to the part. Details of the identification and database requirements are given in Appendix B. Parts without any defects will be stored separately and will not be tagged or entered into the database.

5.4 Notice Of Structural Deficiency

A Notice of Structural Deficiency (NSD) will be raised if fleet representative damage is found. Mechanical damage resulting from the teardown will be excluded. Each independent damage site will receive a unique NSD number except in the following cases. For a FC or DC part that has several closely located damage sites caused by the same loading action, each damage will be assigned an item number under the same NSD. NSDs should be limited to 5 items. For non-critical, secondary parts with closely located damages caused by the same loading action, all damages will be included in the same NSD item. Each damage will be labelled by progressive letters (a, b,c ...).

The NSD numbering system will be NSD - CBYXXXX, where Y represents the number of the centre barrel test article.

5.5 Quantitative Fractography

Parts exhibiting damage may be subjected to QF where they are broken into fragments and the damage surfaces examined under a microscope. The criteria for choosing which parts will undergo QF and the level of investigation that will occur are given in Appendix C.

Defects found during NDI or QF will be defined according to the standard codification system of PSL/DSTO. Details of the defect definitions that may be applied are given in Appendix D.

5.6 Centre Barrel Disposal/Storage Instructions

The centre barrels provide very valuable information for the management of the F/A-18 fleet. Consequently, in accordance with the airworthiness requirements used for the RAAF F/A-18 [6], all centre barrels components found to exhibit damage during NDI will be retained for the life of type. Following the definite retirement of the aircraft from service, disposal of the components in storage will be carried out after the consent of the senior structural integrity officer. Components with no damage may be disposed of prior to this time.

Each component can only be useful throughout the life of the aircraft if it is properly preserved. Consequently, the following are storage instructions for all torn down components exhibiting damage:

a. A teardown identification system will be used to file and label all items exhibiting damage;

b. Critical items will be bagged and sealed with appropriate anti-corrosion measures and then placed in an orderly fashion in well labelled boxes;

c. Critical fractures will be stored in desiccators; and

d. Bigger items are to be placed in properly padded and crated boxes.

5.7 Teardown Report Requirements

The teardown will be followed by a full report documenting the results of the test. The report will include a list of all parts that have exhibited damage which could be represented in the fleet and a summary of the inspection results.

The report will include the QF reports in an Appendix with a table referring to each one. It will also contain a general description of the location where the parts are stored with the number and the list of the boxes used.

6. Conclusion

This plan presents a generic fatigue enhancement and teardown process for ex-service F/A-18 centre barrels sent to DSTO for examination. The fatigue enhancement will require each centre barrel to be fatigue cycled. This will increase the size of potential fatigue cracks and other damage in the ex-service centre barrels and thus potentially increase the number of cracks found. The test rig design and loading requirements have been outlined in this plan. The requirements for centre barrel disassembly, NDI and data storage and analysis, including quantitative fractography have been set out with the aim of ensuring consistent information and data. Finally, the final report will contain standardised information to offer consistency between these examinations and previous full-scale test examinations.

7. Acknowledgements

The authors would like to acknowledge the useful discussions regarding the FINAL program held with Simon Barter and Paul White. They would also like to thank Capt. C. Wortman (CF), Mr M. Kittur (USN NAVAIR), Mr F. Eubank (STLO NAVAIR), SQNLDR Beverly Tubbs (TLO NAS Nth Island) and SQNLDR P. Klose (RAAF) for their valuable assistance in procuring ex-service centre barrels.

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Appendix A: Inspection Cards

Table A1 - FT55 Teardown Inspection Cards to be used in Centre Barrel Inspection

Part	Description	Category	FT55 Teardown Cards [7]
74A324802	Skin, aircraft engine air inlet, FS442 to FS497	Secondary	D36T
74A324804	Skin, aircraft duct outboard, FS442 to FS497	Secondary	D37T
74A324202	Bulkhead, FS453	FC	C1T, C5T
74A324204	Bulkhead, FS470.5	FC	C2T, C6T
74A324206	Bulkhead, FS488	FC	C3T, C7T
74A324336	Former-fuselage centre section, side FS462.5	DC	D39T
74A324354	Former-fuselage centre section, inboard FS462.5	DC	D15T
74A324303	Former-side centre section fuselage, FS478.5 assembly of	DC	D12T
74A324349	Former-fuselage centre section lower centreline FS478.5	DC	D40T
74A324358	Plate, structural aircraft-fuselage centre section, FS470.5	Secondary	D17T
74A324359	Plate, structural aircraft bulkhead to cap, FS488	Secondary	D18T
74A324357	Plate, structural aircraft bulkhead to cap	Secondary	D16T

Appendix B: Identification and Database Requirements

1. Identification Nomenclature

All parts and fragments from the test article that exhibit damage will be tagged with the information specified below.

1.1 Parts Identification

Each part will be tagged with the following information to utilise the existing FT46 teardown system [12]:

a. Test Origin/Part Number and dash number. Each centre barrel test will be numbered consecutively CB1, CB2, etc. to differentiate between parts originating from different aircraft (eg. CB1/74AXXXX-XXXX)
b. Part Name and side, [R] for right, [L] for left if applicable. (eg. FS453 Bulkhead)
c. Disassembly Date (dd-mmm-yy)
d. Hours Tested (number of Simulated Flight Hours cycled under fatigue enhancement)
e. Barcode All parts will have a barcode in the Y0XXX series. The number Y will correspond to the centre barrel being tested. For example, parts from the first centre barrel will have bar codes in the 10XXX series.

1.2 Fragment Identification

Each fragment will be tagged with the following information:

a. Test Origin/ Part Number Each centre barrel test will be numbered consecutively CB1, CB2, etc. to differentiate between parts originating from different aircraft. The part number is the parent part of the fragment (eg. CB1/74AXXXX-XXXX).
b. Unique Fragment Number
    i. Def This defect identification number will be a sequential number for every defect associated with a given fragment. Each fragment may result in several sites that need to be separately identified.
    ii. Frag This fragment identification number will be a sequential number for each fragment created from parts
d. Part Name and side, [R] for right, [L] for left if applicable. (eg. FS453 Bulkhead)
e. Disassembly Date/Fragment Preparation Date (dd-mmmm-yy)
f. NSD Number/ Item Number/ Issue Number: the associated NSD reference, its item and issue numbers (eg. NSD RAAF A21XXX XXXXX-X-X)
g. Co-ordinates (X,Y and/or Z)
h. Hours Tested (number of Simulated Flight Hours cycled under fatigue enhancement plus the number of service hours)
i. Fractography Report Number (eg. FFINAL-0002)

j. Barcode All fragment tags will have a barcode in the 1Y0XXX series. The number Y will correspond to the centre barrel test. For example, parts from the first centre barrel will have bar codes in the 110XXX series.

2. Database Input

All information obtained from the centre barrel will be recorded in a database for use by the RAAF. The information will be stored in the existing FT46 teardown database. Parts from different centre barrels will be identified by the Test Article field. The following sections outline the information to be entered into the database. More detail is provided in the FT46 Teardown Report [12].

2.1 Parts Identification

When a part is removed from the test article the following information will be entered:

a. Part Number This will include a prefix of the centre barrel being tested. (eg. CB174A324202)
b. Part Name
c. Part Status This indicates whether the part has been inspected, investigated fractographically or is in storage.
d. Part Location
e. Test Article Each centre barrel test will be numbered consecutively.
f. Next Assembly Part Number
g. Next Assembly Part Name
h. Criticality
i. Country of Origin
j. Test Block Number
k. Test Line Number
l. Test Hours The number of hours the part was cycled during fatigue enhancement.
m. Previous Hours The number of hours experienced by the centre barrel prior to fatigue enhancement.
n. Total Hours Sum of Test Hours and Previous Hours.
o. Part Removed by Name of the person who removed the part.
p. On Date the part was removed.

Once this information is recorded, the database will be used to create a tag to identify the part.

2.2 Inspection Details

Once the part has been inspected by a qualified NDI technician, the results of each inspection will be entered into the database in the **Inspection Details** section. This will be done from the Create Inspection for this link in the **View Part** page.

2.3 Defect

If a defect is found and it is not considered to have been induced mechanically by the teardown, its details will be entered from the Create Defect link in the **Inspection Details** page.

2.4 Create NSD

A new NSD is raised for every defect found by a test Engineer. It will be created from the Assign New NSD link from the **Defect** page.

Upon raising an NSD, the test Engineer will compare the current defect to existing DILs. If the defect is not covered by any existing DIL, the defect will be flagged for fleet disposition considerations.

2.5 Fragments

For selected defects, the part will be broken into two or more fragments and subjected to fractography. New fragment records must be created for each fragment using the Create Fragment link in the **Defect** page. After recording the fragment details in the **View Fragment** page, a label will be printed for the fragment.

After QF has been performed on the fragment, a Quantative Fractography report will be created on a standard PSL template. This PDF format report will be uploaded onto the teardown database.

2.6 Create Analysis

An association with a PDF format document that gives further analysis for a damage location may be made from the **Inspection Details** or **Defect** pages.

2.7 Final Storage Location

The Move this Part link in the **View Part** page and the Move this Fragment link in the **View Fragment** page should be used to update the location of parts and fragments and ensure proper tracking of parts and fragments.

Appendix C: Quantitative Fractography

1. Quantitative Fractography Decision Flow Chart Development

Once the preliminary inspections have been performed in accordance with the steps highlighted in Section 5.2, the flow chart given in Figure C.1 will be used to assess which parts will be subjected to QF analysis. Not all components will be subjected to further analysis in the form of QF. For reasons of time, cost and efficiency it is necessary to limit QF to the areas that are likely to change the outcome of previous decisions, provide new information, or will provide sufficient information to ensure the structural integrity of the aircraft can be more efficiently managed.

2. Factors in Establishing QF Priorities

QF analysis is divided in two main categories: the "A" group and the "B" group. The "A" group addresses all items that are safety of flight. The "B" group items will usually be those that have an economic impact on fleet management or would be of scientific interest to the Risk and Reliability program and therefore will have QF analysis performed later. Within each group, there will also be a subsequent prioritisation to ensure those locations that have the most serious impact will be addressed first. Some of the factors affecting priority are:

a. Damage that does not have a RAAF Damage Item Location (DIL) [5] should be high priority. This is a damage location that has not been seen in previous testing or fleet experience, so this new information is important for fleet decisions.
b. Items due to be modified at SRP1++ should have lower priority to other equivalent "A" group or "B" group items unless the defect was located within a previously repaired region.
c. If there are several cracks of the same failure type in a local area (for example fastener hole cracks), cracks apart from the largest crack should have lower priority.
d. Higher priority should be given to details where there is a specific interest including:
   i. The need to confirm the nature of crack initiation;
   ii. When there are doubts that the surface finish is hiding damage;
   iii. When there are uncertainties about crack morphology;
   iv. The area may have failed in another test or in service; and
   v. When assessments indicate that the defect was close to failure during the service life of the aircraft.

3. Interpretation of Fractographic Results - Analytical technique

There will be three levels of fractography carried out:

a. Full Quantitative Fractography: Performed when there is a need to produce a crack growth curve, and to use this curve to interpret test results and determine the effectiveness of initiating flaws. This may include the comparison of this result with coupon data. For difficult to interpret cracking (e.g. flange bending radii), the development of new methods of interpretation with the specific aim of using the results to aid in the lifing of the component will be carried out;

b. Quantitative Fractography: In this case, only crack growth curves will be produced. They will be used to assess the rate of growth of a given defect and could potentially be used to derive inspection intervals; and

c. Partial Fractography: This level of analysis would be used to identify the initiating flaw and the size and shape of the crack and/or the general nature of the cracking.

Figure C1 presents the logic to be followed in defining QF requirements. A standard QF format has been developed, details of which will be included in the final report. All QF reports need to be produced in this format, though some data may be omitted for the partial analysis. The reports will form part of the final teardown report.

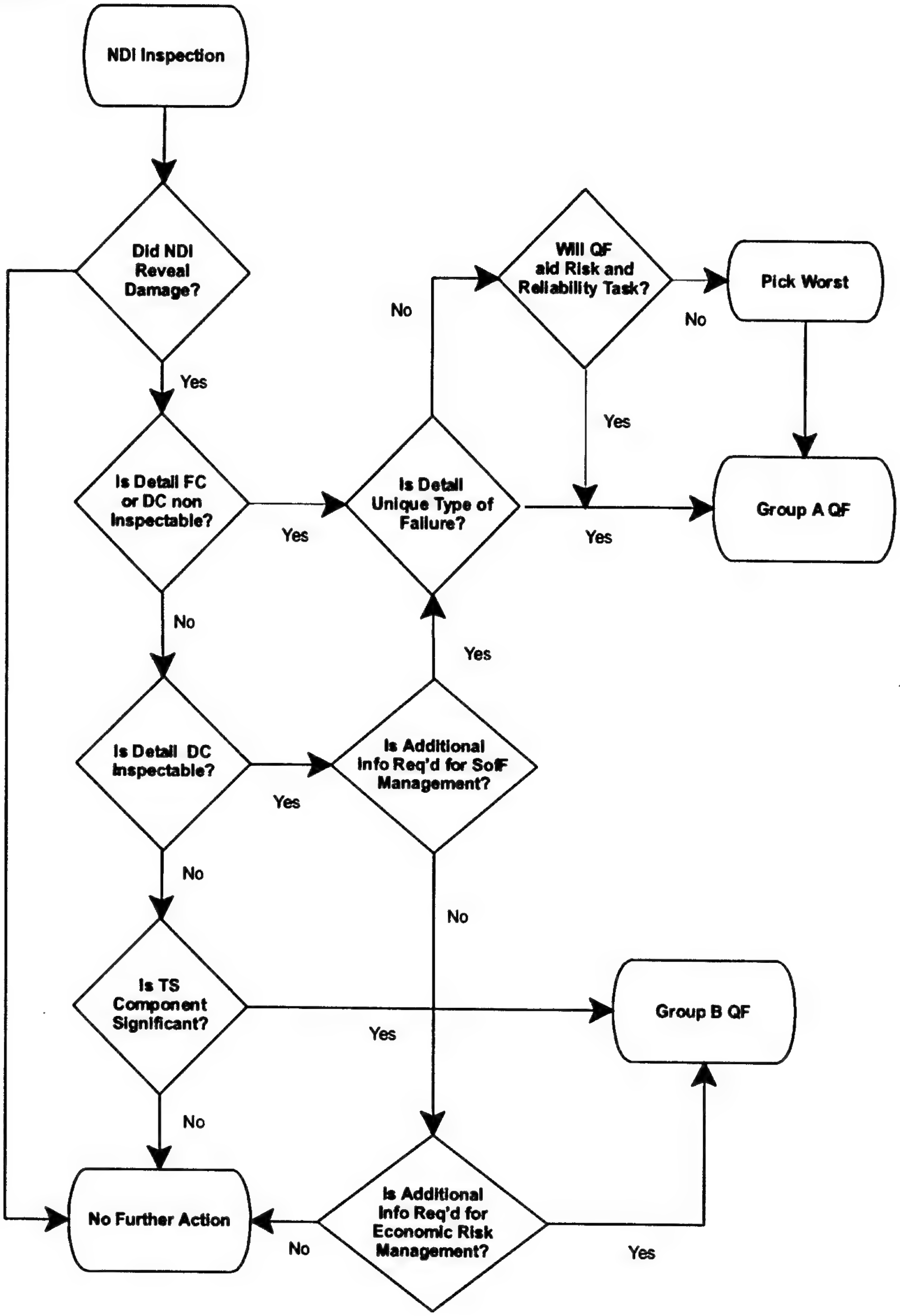


Figure C1 - QF Decision Flow Chart

Appendix D: Defect Definitions

1. Defects Codification

This Appendix has been reproduced from Appendix E of the generic IFOSTP teardown methodology report [4].

A standard codification system has been devised by PSL/DSTO to describe discontinuities. This system will be used in part for the purpose of the centre barrel teardowns. The codes will be used in the database as searchable fields and will also be used in the QF report to describe the damage. Discontinuities detected during the NDI or QF will have the following discontinuity codes.

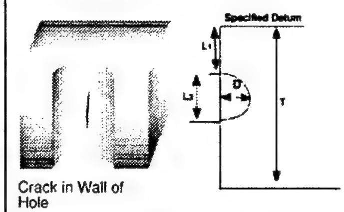
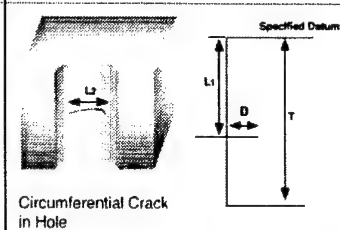
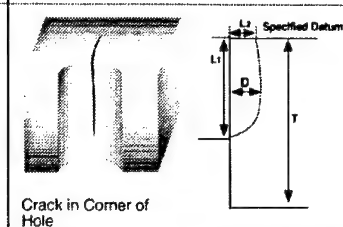
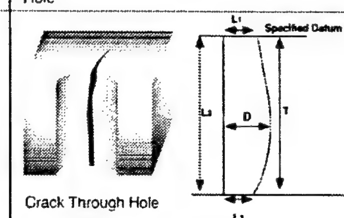
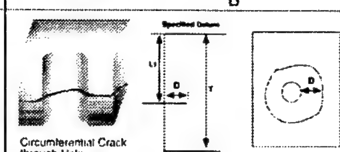
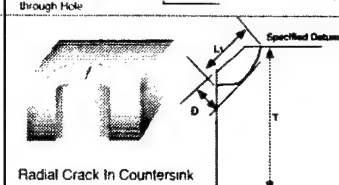
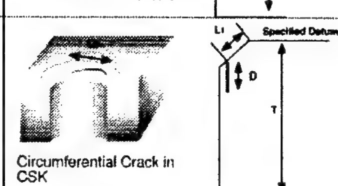
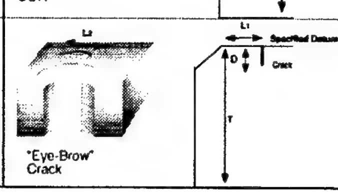
There are 3 levels of potential damage that can be recorded with this codification system. They are presented in tables D1 – D3 and are as follows:

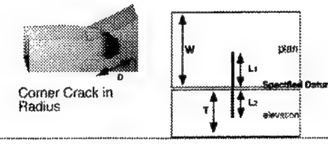
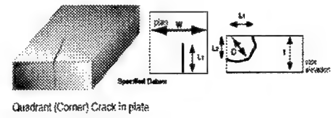
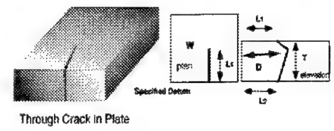
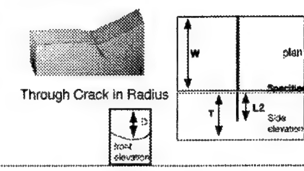
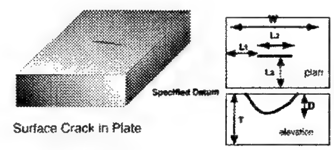
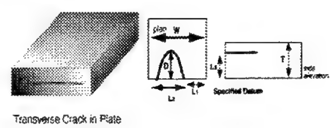
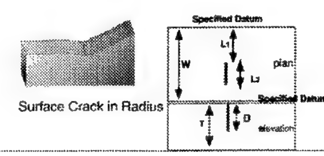
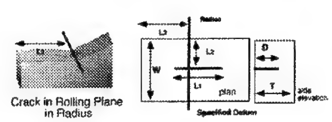
a. Fatigue Damage;

b. Mechanical Damage; and

c. Corrosion Damage.

Table D1 – Standard Damage Type - Fatigue Defects Codification Table

Standard Damage Type (Crack Types)	Code	Diagram (Input Fields)
Hole Wall Crack	HWC	
Hole Peripheral (Circumferential) Crack	HPC	
Hole Quadrant Crack	HQC	
Hole Through Thickness Crack	HTC	
Hole Peripheral (Circumferential) Through Crack	HPTC	
Hole Radial Countersink Crack	HRKC	
Hole Peripheral (Circumferential) Countersink Crack	HPKC	
Eyebrow Crack	HEC	

Corner (Quadrant) Crack in Radius	**RQC**	
Plate Quadrant Crack	**PQC**	
Plate Through Thickness Crack	**PTC**	
Through Thickness Crack in Radius	**RTC**	
Plate Surface Crack	**PSC**	
Plate Internal (Planar or Transverse) Crack	**PIC**	
Surface Crack in Radius	**RSC**	
Rolling Plane (Planar or Transverse) Crack in Radius	**RIC**	
Other Cracks	**OCT**	L
De-bond	**DEB**	L, W, A
Delamination	**DLN**	L, W, A
Blend	**BLD**	L, W, D, A
Other	**OTH**	L, W, D, A

Legend: L - Length A - Area T - Thickness
W - Width D - Depth

Note: Every hole cracks will require a clock/angle reference. All references will be from a position either looking forward, down or inboard to the aircraft.

Table D2 – Standard Damage Type – Mechanical Defects Codification Table

Standard Damage Type (Mechanical Types)	Code	Input Fields
Dents	DEN	L, W, D, A
Scratches	SCR	L, D
Gouges	GOU	L, D, W
Scores	SCO	L, D, W
Nicks	NIK	L, D, W
Machine tears	MTR	L, D, W, A
Mis-drilled holes	HOL	L, D, W
Elongated Holes	ELN	D
Other	OTH	L, D, W, A

Legend: **L – Length** **W – Width** **d – diameter**
D - Depth **A – Area**

Table D3 – Standard Damage Type – Corrosion Defects Codification Table

Standard Damage Type (Corrosion Type)	Code	Input Fields
Uniform (General) Corrosion	UNCN	L, W, A, D
Pitting Corrosion	PTCN	L, W, A, D, P, De
Intergranular Corrosion	INCN	L, W, A, D
Exfoliation Corrosion	EXCN	L, W, A, D
Galvanic Corrosion	GACN	L, W, A, D, C
Crevice Corrosion	CRCN	L, W, A, D
Fretting	FRCN	L, W, A, D
Filiform Corrosion	FICN	L, W, A, D
Stress Corrosion Cracking	SCCN	L
Corrosion fatigue	FACN	L
Hydrogen Embrittlement	HECN	L

Legend: **L-Length** **W-Width** **A-Area (maximum or estimated)**
D-Depth (maximum) **P-Pit depth (maximum)** **De-Density**
C-Coupling material

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B. Dixon and L. Molent

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19. ABSTRACT

This report provides a generic plan for fatigue cycling and teardown of ex-service F/A-18 centre barrels for the purpose of fatigue flaw identification. It describes the accelerated fatigue test cycling program which will be applied to each centre barrel to increase the size of existing microflaws or defects so that they can be more reliably detected. It also covers the teardown, inspection and storage requirements of the project.